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Cost and Performance Report

(CP-0005)

Oil/Water Emulsion and Aqueous Film Forming Foam (AFFF) Treatment Using Air-Sparged Hydrocyclone Technology

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LIST OF ACRONYMS

AFB	Air Force Base
AFFF	Aqueous Film Forming Foam
AFRL	Air Force Research Laboratory
ASH	Air-Sparged Hydrocyclone
AST	Above-Ground Storage Tank
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CTC	Concurrent Technologies Corporation
DAF	Dissolved Air Flotation
dBA	Decibel
DoD	Department of Defense
EPA	Environmental Protection Agency
FOG	Fats, Oils and Grease
FFTF	Fire Fighting Training Facilities
gpm	Gallons per minute
HP	Horsepower
LCS	Lab Control Sample
LCSD	Lab Control Sample Duplicate
MCB	Marine Corps Base
MDL	Method Detection Level
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MSDS	Material Safety Data Sheet
NA	Not Available
NS	Naval Station
NFESC	Naval Facilities Engineering Service Center
NPDES	National Pollutant Discharge Elimination System
O&G	Oil and Grease
OEL	Occupational Exposure Limit
OSHA	Occupational Safety and Health Act
PEL	Permissible Exposure Limit
POC	Point of Contact

LIST OF ACRONYMS (continued)

POL	Petroleum, Oil and Lubricants
POTW	Public-Owned Treatment Works
ppm	Parts per million
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RO	Reverse Osmosis
RPD	Relative Percent Difference
SBIR	Small Business Innovation Research
scfm	Standard cubic feet per minute
SHSC	Site Health and Safety Coordinator
TCLP	Toxicity Characteristic Leaching Procedure
TDP	Technology Demonstration Plan
TRPH	Total Recoverable Petroleum Hydrocarbons
TSS	Total Suspended Solids
USAF	United States Air Force
VOC	Volatile Organic Compound

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Captain David Kempisty, USAF, and Mr. John Spivey of the Air Force Research Laboratory (AFRL) managed this project. ESTCP documentation was completed by Richard Baker of Kemco Systems, Inc. with the aid of Dr. Gerry Van Gils of Kemco Systems, Inc (who also served as Principal Investigator for the project) and Capt Kempisty of AFRL. Development work for the project in SBIR Phase I and II was performed by Dr. Ye Yi of Advanced Processing Technologies (APT). Dr. Richard Lee of the Naval Facilities Engineering Service Center (NFESC) served as the project liaison from the US Navy. Kemco Systems, Inc. was responsible for the design, manufacture and operation of the system used for demonstration and testing. Test locations were selected by AFRL, and facility/project interaction was conducted by John Spivey of AFRL. Sample analyses were conducted by Southern Analytical Laboratories of Oldsmar FL, with AFFF analysis being conducted by Dr. Ye Yi. Other contributors included Richard Hamblin and William Mitchell, system technicians from Kemco Systems Inc.

Points of contact can be found in Appendix A.

Technical material contained in this report has been approved for public release.

1.0 EXECUTIVE SUMMARY

Many Department of Defense (DoD) activities create waste streams that contain petroleum-based substances (fuels, oils and greases), emulsifying agents, semi-soluble and soluble liquid materials, including fire fighting chemicals such as Aqueous Film Forming Foam (AFFF) and other fire-fighting surrogates used for the suppression of combustible and flammable liquid fuel fires. Common waste stream sources from DoD activities include motor pool and aircraft wash rack wastewater, fuel tank cleaning wastewater, storm drain wastewater and fire fighter training wastewater. Significant research efforts have been conducted by the U.S. Air Force and Navy during the past several years to develop and identify technologies that could effectively treat waste streams with high oil and grease (O&G), total suspended solids (TSS), and/or AFFF within acceptable cost and time requirements. Many different technologies have been evaluated. These included biological treatment, reverse osmosis (RO) and other physical-chemical removal methods.

The most effective of all the physical removal methods reviewed and evaluated was Air-Sparged Hydrocyclone (ASH) technology. The ASH system combines froth flotation principles with the flow characteristics of a hydrocyclone. This system has proven to provide excellent O&G separation as well as extremely efficient AFFF removal. The objective of this demonstration was to validate and quantify the effectiveness of the ASH system for removing emulsified fuels, O&G, AFFF (and other fire-fighting foam surrogates), in a commercially viable manner, from a variety of waste streams generated by DoD facilities. The system was evaluated during short-term (1 day) field tests/demonstrations at nine DoD sites from November 2000 to July 2001. Another important objective was to allow a wide audience to witness the ASH technology in operation, facilitating technology transfer.

System validation was established through the analysis of the treated waste stream for criteria including concentrations of O&G, Total Recoverable Petroleum Hydrocarbons (TRPH), Total Suspended Solids (TSS), Aqueous Film Forming Foam (AFFF), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Success was determined by comparing these levels against the local discharge limits in each contaminant category for the individual site location. In the absence of a regulatory limit for AFFF, an overall target value of <50 ppm was used. The ASH system met its primary objective of demonstrating and quantifying the system's ability to effectively treat O&G/AFFF waste streams throughout the nine demonstrations. It also showed versatility and was easy to operate. Results showed average O&G and TRPH removal rates of >87% and an average AFFF removal rate of >90%, with effluent in all instances discharged at the desired target value of <50 ppm AFFF. These results were achieved consistently throughout the demonstrations. Each stream contained varying types and concentrations of contaminants. Some contained O&G only, some AFFF only, and others contained a combination of both. Even in case of high AFFF concentration (>500 ppm), operation of the system in a batch recirculation mode gave the desired 50 ppm AFFF effluent. In most instances the sludge (concentrate) remaining from ASH processing was less than 10% of the original stream volume, and in many cases was lower than 7%. Toxicity Characteristic Leaching Procedure (TCLP) testing showed that this concentrate was non-hazardous.

Capital costs for ASH systems are dependent on unit size and features included but base system costs range from $173,000 for a 5- gpm system (2 stage, skid mounted with blower) to $224,250 for a 150-gpm system (2 stage, skid mounted with blower). Operational costs (excluding labor costs and amortization of capital), were dependent on the stream-specific contamination characteristics

and ranged from \$0.17/1000 gallons treated (AFFF treatment with no chemical treatment) to \$2.54/1000 gallons treated (for extremely high O&G concentration). Current disposal methods and costs and annual volume to be treated vary dramatically from location to location. Therefore, payback on an ASH system is variable. It could be as short as a few months if annual volumes to be treated and off-site disposal costs are both high. In cases where treatment volumes are low (requiring ASH operation for less than 30 hours per year) the payback period may reach 7 years based on current disposal costs. Implementation of the system into DoD sites has already begun with the delivery of a 50-gpm, 2-stage, trailerized system to Naval Station Mayport, FL.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

AFFF poses environmental concerns and raises questions about its long-term use due to its resistance to biodegradation, high COD, toxicity and its extreme foaming capability. In fact, some U.S. sanitation districts prohibit the discharge AFFF wastewater into their plants unless the AFFF concentration is less than 50 ppm. Other industrial wastewater treatment plants throughout the country also restrict the discharge of AFFF wastewater into their local wastewater stream, each with its own concentration limits.

Significant research efforts have been conducted by the Air Force and Navy during the past several years to develop and identify technologies that can effectively treat wastewater with high concentrations of fuel, fats-oil-grease (FOG), COD, total suspended solids (TSS), and/or AFFF within acceptable cost and time requirements. Technologies evaluated include reverse osmosis (RO) and other physical-chemical removal methods.

The high wastewater volumes and flow rates in consideration discourage direct utilization of RO or any other filtration technology without prior volume reduction. The most promising economical method to remove the contaminants from the waste stream is via a physical removal and concentration method, followed either by direct disposal or additional treatment by RO. In this arrangement, voluminous oil, grease and AFFF containing wastewater is processed by a physical removal method that quickly concentrates the contaminants in a cost-effective manner. The processed water can then be discharged and the concentrate can be either directly disposed or treated again with RO technology for further concentration prior to disposal.

The most promising physical removal method is Kemco Systems, Inc.'s (hereafter referred to as Kemco) Air-Sparged Hydrocyclone (ASH) technology. The ASH system combines froth flotation principles with the flow characteristics of a hydrocyclone and has been proven to provide excellent O&G separation as well as AFFF removal.

Oil separation in a centrifugal force field developed in a hydrocyclone provides an advantage with respect to capacity when compared to other equipment used for oil/water separation. However, the classical hydrocyclones may not be amenable for separation of liquid/liquid dispersions. For liquid/liquid cyclones, the requirement for efficient separation is a high pumping rate, resulting in a significant head loss on a single unit and a high equipment cost. An alternative technology to remove oil is froth floatation. Since hydrocarbon oils are hydrophobic in nature, froth flotation has been applied to separation of oil from oil/water emulsions. With the aid of surfactants, polyelectrolytes and/or inorganic coagulants, moderately stable emulsions can be treated and removed. Froth flotation has limited capacity and high equipment/operation cost is required to employ the technology to handle oil/water streams. Further, conventional froth flotation technology cannot handle AFFF-laden wastewater due to excessive foam generated by the AFFF.

In the case of fine particle and/or oil removal, the design features of the ASH system improve the floatability of fine particles/oil droplets in two ways. First, a strong centrifugal force field is developed, the magnitude of which is determined by the tangential velocity of the suspension and the cyclone diameter. This centrifugal force field results increases the inertia of fine hydrophobic

particles/oil droplets and hence facilitates their attachment to air bubbles. Secondly, the high-speed swirl flow exerts a considerable shear force at the porous wall. This, coupled with the fact that the air phase is introduced through extremely fine pores in this porous wall, generates numerous small air bubbles, which is another condition that can be shown to facilitate the flotation of the fine hydrophobic particles. As a result, the probability of collision of air bubbles with the O&G droplets is significantly increased to such an extent that the collision event is no longer a rate determining process. After attachment, the bubble/particle or bubble/O&G aggregates travel only a very short radial distance across the swirl layer. As a consequence, effective floatation of fine particles or O&G droplets can be achieved at a residence time of less than a second, which approaches the intrinsic bubble/particle attachment times.

2.2 PROCESS DESCRIPTION

In the ASH process, the O&G/AFFF-containing wastewater is pumped from the waste stream source into the first wastewater tank. The water is then carried in series through a total of three tanks, with each tank providing mixing and hydraulic retention time required for adequate chemical treatment of the waste stream. Polymer and metal coagulant may be added (if required for the particular waste stream) into the first two wastewater tanks by use of chemical pumps. The wastewater chemical mixture is vigorously mixed in the two tanks by means of a paddle mixer. Any additional chemical required may be injected into tank three, where it is also mixed. The pretreated waste stream is then pumped from the third wastewater tank through ASH 1 pump to the first ASH unit. The wastewater is introduced tangentially into the ASH chamber to develop a tangential swirl flow of water on the inside of a porous tube, which is contained within a jacketing chamber. When pressurized air is forced into the jacketing chamber and passes through to the inner surface area of the porous tube, it is immediately sheared by the tangential swirl of water and forms numerous fine bubbles or foam. The bubbles attach to fine particles and/or oil droplets in the water. For removal of AFFF or any other foam-generating compound (which are surfactants that concentrate at the air/water interface to generate stable foams), the air strips AFFF from the water by utilizing AFFF's own foam-forming capabilities and is concentrated at the air/water interface of these fine bubbles. Figure 1 illustrates the flow process of a single ASH unit.

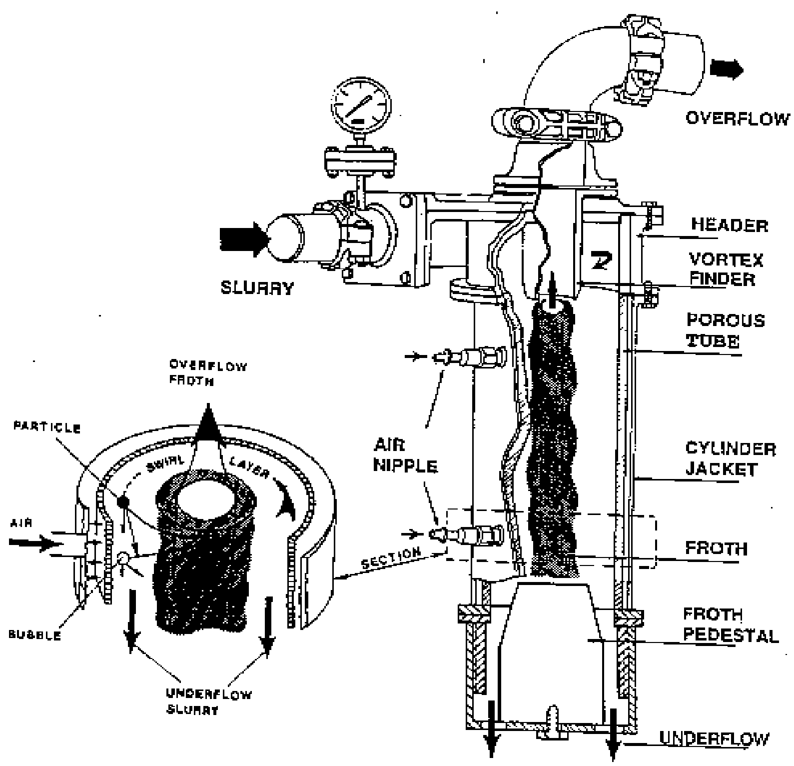

Figure 1. Air-Sparged Hydrocyclone (ASH) Process.

The processed water is discharged from the bottom of the ASH unit into another tank. Water discharged from the underflow of ASH 1 enters a clarifying chamber where floating sludge is removed via a skimming system into the overflow/sludge tank. The clarified water flows over a weir into a clearwell, which serves as the feed for the second stage pump. This process is repeated for the remainder of the four ASH stages. A given wastewater can be treated by 4 successive ASH stages and then discharged. Alternatively, when the system is operated in a batch mode, the wastewater can be re-sent through as many stages (repeatedly) as necessary to meet the specific discharge quality standards.

The overflow from each of the four stages flows out of the top of each ASH unit to avoid trapping excessive water. Adjusting the ratio of available flow areas of the underflow and overflow of the ASH unit controls the flow rate carried into the overflow. The overflow volume of liquid generated from ASH processing ranges from 1 to 10 % of influent flow volume. The overflow percentage required is dependent on the initial O&G and AFFF concentration of the wastewater as well as discharge limits for the effluent water. A de-foamer can be sprayed into the overflow/sludge tank in order to suppress the foam therein to a small quantity of liquid for disposal. A system flow schematic (Figure 2) and an equipment layout (Figure 3) of the ASH system are included to provide a basic understanding of system components and flow paths. A more detailed description of the ASH system can be found in AFRL (1988)(1).

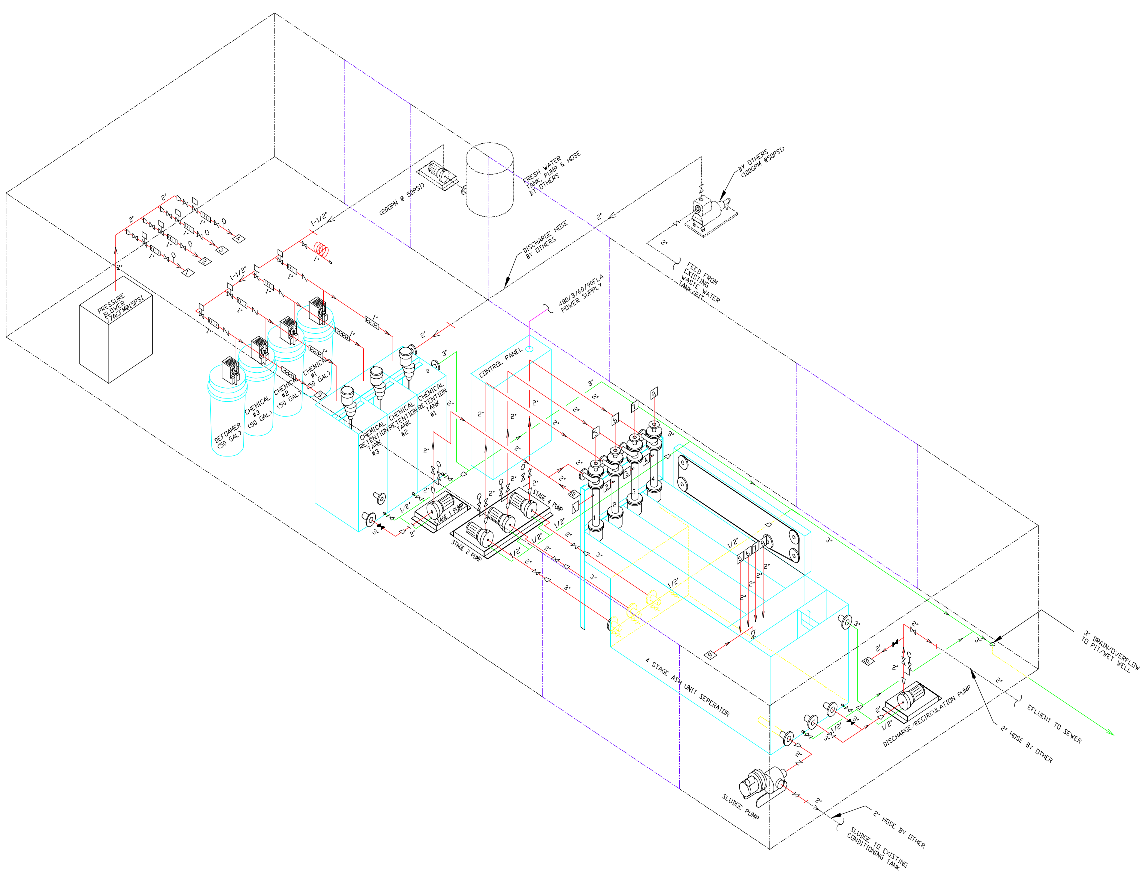

Figure 2. ASH System Schematic Flow Diagram.

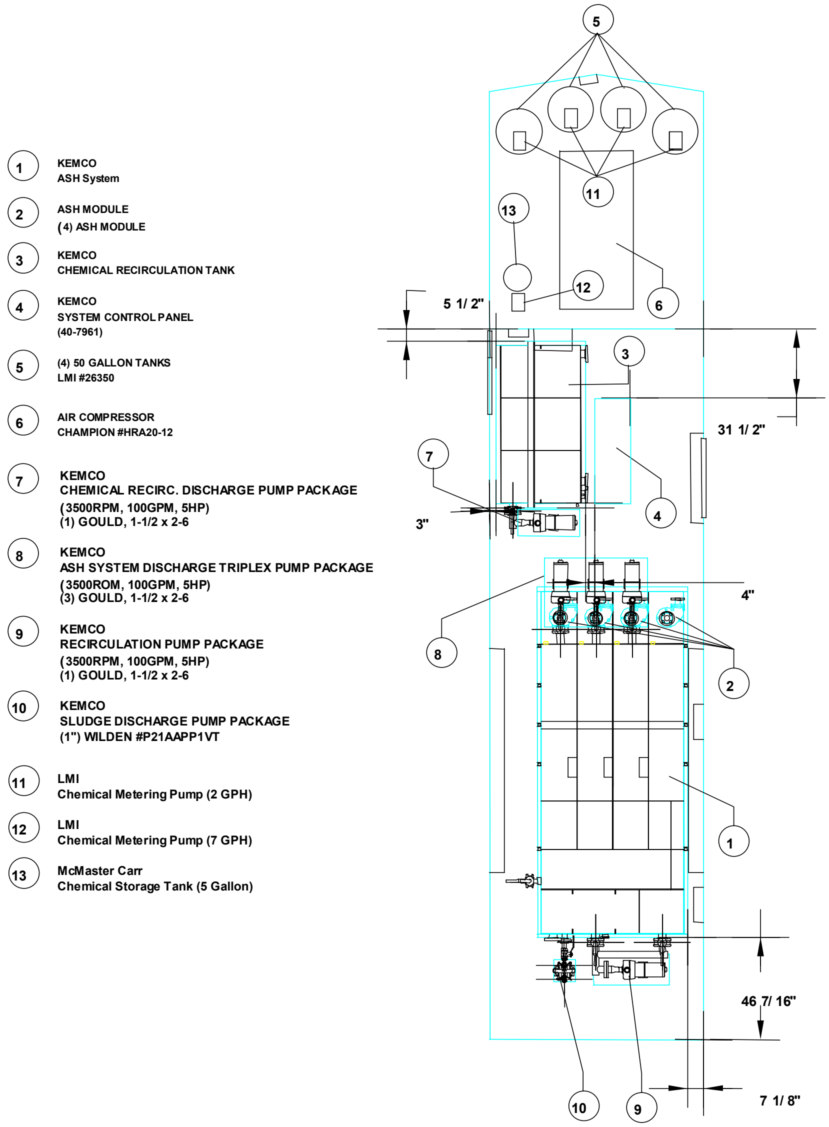

Figure 3. ASH System Equipment Layout.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

Extensive testing of this technology has previously been performed at many DoD sites on a variety of types of waste streams, details of which may be found in the Final Report(2). Final Reports for Phase I(3) and Phase II(4) SBIR projects, as well as independent reports from the Navy Environmental Leadership Program(5) (conducted by Concurrent Technologies Corporation) and Naval Facilities Engineering Service Center(6), are also available for review.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

2.4.1 System Advantages

ASH technology has much strength when compared to other waste treatment technologies. With respect to AFFF and other fire-fighting foam treatment, ASH is the only practical type of aeration technology. The ASH system uses the AFFF's capacity for foam formation as a part of the removal process. Other aeration technologies, such as Dissolved Air Flotation (DAF), cannot be used for this type of removal due to the excessive and unmanageable quantities of foam, which would be generated. In handling other waste stream contaminants, this technology also provides a means of reducing O&G and hydrophobic particulate contaminant concentrations to very low levels while maintaining a capability to handle relatively large volumes of wastewater.

The capability of the ASH system to handle large flow rates of waste stream with low effluent concentrations is supplemented by the following system characteristics.

- **System Mobility:** The system can be moved from site to site to treat a waste stream at its remote location. This provides the ability to treat a wide variety of waste streams and locations with a single unit. The system can be easily moved with minimal towing requirements.

- **Treatment of Differing Waste Streams:** The unit is designed with enough versatility in the number and type of chemical additions, and the number of stages of treatment, to be able to handle waste streams with a multitude of contaminant variations and contaminant concentration levels. This yields excellent results in the removal of AFFF, other fire fighting foams, O&G, hydrophobic materials, particulate contaminants lighter than water, and Volatile Organic Compounds (VOCs) (by virtue of the system's air stripping capability).

- **Small Waste Disposal Volumes:** The ASH system, while having the capability to handle relatively large volumes of wastewater, generates a very small quantity of concentrated, non-hazardous, disposable waste. The volume of the waste stream in most cases is less than 10% of the total influent waste stream volume.

- **Small System Footprint:** The ASH system requires much less physical space for its operation than other waste treatment technologies when compared on the basis of volume of wastewater treated and/or quality of effluent water.

- **Short Retention Time/High Surface Loading:** The unit requires a much lower waste stream retention time and can handle a much larger surface loading than other treatment methods while achieving equivalent or better effluent results. This allows for larger volumes of wastewater to be passed through a unit whose size remains relatively small. Technologies such as nano-filtration and ultra-filtration can provide better overall contaminant removal rates but are severely limited in total processing capacity.

- **Low Operational Cost:** The ASH system can treat waste streams in a much more cost effective manner than other treatment options with equivalent effluent results, based on treatment volume. Operating costs are reduced by the fact that fewer chemicals, as well as

smaller quantities of those chemicals, are required than with other treatment methods to yield equivalent results. This results in a smaller volume of residuals (sludge) generated, which also reduces overall operating costs.

The ASH technology compares favorably against conventional technology for the removal of oily wastes and AFFF. This includes such conventional systems as oil skimmers, inclined plate separators, DAF, membrane filtration, pressure filtration and hydrocyclones. Although this current study is not a definitive comparison of ASH versus the other technologies, there are several salient points, as follows.

- The ASH process excels in the removal of emulsified oils as well as free oils, which is an advantage over oil skimmers or conventional oil/water separators. Inclined plate clarifiers are effective in separation of settleable solids from the bulk liquid but not materials that are less dense than water.

- DAF technology, while closest to ASH in performance, requires 2 to 3 times the area for treatment due to the lower surface loading rates and higher hydraulic retention times required. Also, the removal of AFFF is not accomplished.

- Membrane filtration using ultra-filtration membranes has been effective in treating oily waste. However the cost for these membranes systems far exceeds the ASH system cost.

- Pressure filtration is not practical on oily waste streams with significant concentration due to the fouling of filtration media such as sand, diatomaceous earth or other media.

- Hydrocyclones, while able to address the more dense particles, do not remove the less dense materials or foam as efficiently as ASH.

2.4.2 System Limitations

The ASH process, despite all of its strengths, does have a few limitations, which are detailed below.

- **Limited Concentration Reduction:** The ASH technology is extremely efficient at the removal of a wide variety of contaminants (up to 99% removal of O&G, and 70-90% removal of fire-fighting foam surfactants). However, it cannot achieve 100% removal of most contaminants or the removal levels achievable with technologies such as RO, nano-filtration and ultra-filtration. It should be noted that, though these technologies provide excellent concentration reductions, their processing capacity is severely limited.

- **No Ionic Removal:** The ASH system is incapable of the removal of truly dissolved monovalent and bivalent ionic materials (such as Na+ and Cl- from NaCl).

- **Limited Heavy Particle Removal:** The ASH system also has difficulty in removing non-hydrophobic particle contaminants, which are "unfloatable" or heavier than water. This is because the system uses floatation to separate and remove contaminants.

3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

The primary performance objective of this project was to validate and demonstrate the effectiveness of the ASH system for the commercially viable treatment of waste streams, generated at different DoD installations, containing various types and concentrations of contaminants including O&G and AFFF.

The success of the validation was determined through the analysis of the treated waste stream. Contaminant concentration levels were evaluated against end point criteria established as the local discharge limits for each category. The system was designed to treat streams specifically for removal of O&G and AFFF. The performance criteria of the system were based on the system's ability to reduce these contaminants to levels below existing permitted discharge limits. In the absence of an AFFF regulatory limit, a target value of <50 ppm was used. AFFF concentration reduction in instances of high AFFF concentration required operation of the system in a batch recirculation mode to reach 50 ppm AFFF levels. Evaluation of other stream contaminant concentrations, including BOD, COD, TSS and TRPH, was conducted to demonstrate the system's ability to remove these contaminants. Results of the specified performance criteria (O&G and AFFF removal) are provided for each site in Section 4.0.

Qualitative performance objectives such as reliability, automated operation, ease of operation, mobility and versatility were evaluated throughout system operation at all demonstration sites. Relatively short demonstration times at each site tested the system's ease of operation, setup and tear down as well as automation capabilities. The schedule for the testing provided evaluation of the system's mobility and reliability. Each of the nine sites offered varying types and concentrations of contaminants, which the system was designed to process. By processing such a variety of streams and conditions, the equipment demonstrated its extreme versatility.

3.2 SELECTION OF TEST SITE/FACILITY

The sites selected for demonstration were chosen to maximize DoD exposure to the technology. This was accomplished by providing nine demonstration locations in three distinct geographic regions (Eastern, Mid-Continent and Western). The site selections also took into account the characteristics of particular waste streams. A variety was sought to test the flexibility of the system. The sites chosen for demonstration are listed in Table 1.

Table 1. Demonstration Site Summary.

Demonstration	Demonstration Site Location	Test Dates	Test Scope
1	Naval Station Mayport, FL	11/7/00 - 11/9/00	O&G & AFFF Removal
2	MCB Camp Lejeune, NC	12/5/00 - 12/7/00	O&G Removal
3	Tyndall Air Force Base, FL	1/9/01 - 1/11/01	O&G & AFFF Removal
4	Goodfellow Air Force Base, TX	1/30/01 - 2/2/01	O&G & AFFF Removal
5	Tinker Air Force Base, OK	4/24/01 - 4/26/01	AFFF Removal
6	Hill Air Force Base, UT	5/8/01 - 5/10/01	O&G Removal
7	Edwards AFB, CA	6/12/01 - 6/14/01	O&G Removal
8	MCB Camp Pendleton, CA	6/26/01 - 6/28/01	O&G Removal
9	NS Pearl Harbor, HI	7/23/01 - 7/31/01	O&G & AFFF Removal, AFFF only Removal

3.3 TEST FACILITY HISTORY/CHARACTERISTICS

Site histories and maps are provided in more detail in the Technology Demonstration Plan (TDP)[7], Supplemental TDPs and Final Project Report[2]. The descriptions of each site provided below describe the demonstration of the ASH technology at each site.

3.3.1 Naval Station Mayport, FL

The particular waste stream treated at Naval Station (NS) Mayport was ships' bilge discharge water. This stream contained AFFF, oil emulsions, grease, fuel and surfactants. A baseline waste stream characterization of the water treated was provided prior to demonstration testing by CTC (consultants for NS Mayport). This can be found in Supplemental TDP for the East Coast Region as well as in Appendix C of the Final Project Report[2].

The oily water treatment plant at NS Mayport performs preliminary treatment of ship bilge water prior to its introduction to the sewage treatment plant. It processes a total volume of approximately 1.2 million gallons per month, of which approximately 10% is made up of ship bilge water. AFFF from shipboard fire suppression presents treatment issues due to its foaming characteristics and potential adverse environmental impacts on surface water if not removed. In 1997 a shock loading of AFFF-contaminated sewage caused a shut down of the sewage treatment facility, which eventually led to a significant treatment cost for the contaminated sewage, as well as for the re-initialization of facility operation.

3.3.2 Marine Corps Base Camp Lejeune, NC

A large volume of waste containing primarily oil emulsions generated from activities within the motor transport section was treated during the demonstration at MCB Camp Lejeune. It contained oil, grease, soap, emulsions and gasoline, each in unique concentrations. The specific waste stream characteristics and applicable POTW limits were not provided by the installation.

The ASH type of pretreatment operation at MCB Camp Lejeune would prevent problems at on-site treatment facilities and carry-thorough to surface water or fouling of public treatment works.

3.3.3 Tyndall Air Force Base, FL

The specific waste stream treated at Tyndall AFB was from the aircraft wash rack, the motor pool and the fire-fighting training pit. The volume of waste generated from these streams is approximately 8,000 gallons per day and the primary contaminants of concern include JP-8 fuel, oil and AFFF. This waste stream is presently treated by aeration and oil/water separators, or is sent directly to holding ponds from which the waste is pumped to trucks and transported for off-site treatment. Specific waste stream characterization and applicable POTW limits were not provided by the installation.

3.3.4 Goodfellow Air Force Base, TX

The fire-fighting training wastewaters at Goodfellow AFB pass though an oil/water separator to remove any free-phase product and settle out any sludge before going into a 500,000-gallon above-ground storage tank (AST). However, the current system is severely uinder-designed and does not effectively accomplish either of these objectives. The AST has accumulated sludge, emulsions and oils along with the water, making the water unsuitable for reuse.

The results of several sets of laboratory water analysis from samples collected within the waste treatment system are included in Appendix C of the ESTCP Final Project Report(2). The specific waste stream characteristics for this site were more than likely a combination of the sets of data contained in that appendix. The applicable POTW limits for this site were not available.

3.3.5 Tinker Air Force Base, OK

The waste stream treated at Tinker AFB was from the on-site storage of AFFF-containing fire-fighting water in open-air retention ponds. These ponds collect rainwater run-off but AFFF contaminated water, which remains in the fire trucks at the completion of fire-fighting or fire-fighting training exercises, is also discharged to these ponds. Very little O&G contamination was present. There was, however, some residual red clay from rainwater run-off, which contributed greatly to the particulate matter. Specific waste stream characterization, including applicable POTW limits were not provided for this site.

Tinker AFB currently employs three such storage ponds on site for the purpose of residual AFFF-contaminated water storage and disposal. The current treatment method is to pump out the ponds when they approach capacity and have the water trucked away for off-site treatment and disposal. It is estimated that each of the three ponds requires emptying approximately twice a year.

3.3.6 Hill Air Force Base, UT

The current treatment system at the vehicle maintenance facility at Hill AFB uses six distinct oil/water separators, ranging in capacity from 250 to 3,000 gallons. Wastewater is directed from a stream generation point (i.e. paint bay wash, vehicle wash, etc.) to its corresponding oil/water separator. After passing through the oil/water separators, the water is discharged to the sanitary

sewer system if it is no longer heavily contaminated. Lack of proper system maintenance has caused system fouling, plugging of feed lines to the separators, and complications arising from heavy storm events.

The waste stream for demonstration at Hill AFB resulted from the steam cleaning of engines after it has passed through an oil/water separator. It contained a variety of contaminants including oil, grease, soap, emulsions, paints, antifreeze and gasoline each in unique concentrations. The primary concern with the waste stream was oil emulsions. The specific waste stream characteristics and applicable POTW limits were not provided for this site.

3.3.7 Edwards Air Force Base, CA

The planned waste stream for the demonstration at Edwards AFB was from aircraft wash racks, aerospace ground equipment maintenance and vehicle wash-rack wastewater. The contaminants in this waste stream include oil, fuel, hydraulic fluid, soap emulsions, antifreeze and other vehicle fluids. The current treatment method is to pump the waste to trucks, which then transport it to an off-site treatment and disposal facility.

However, upon jar testing at the site and subsequent investigation into the waste stream source, it was determined that the water came from a very wide variety of activities. These included parts cleaning (industrial solvents), wash rack, motor pool solid waste de-watering, photo processing and a variety of other base-wide activities. The waste stream included unanticipated VOC and semi-volatile contaminants, which were not efficiently treated using the chemistry available on board the ASH trailer. Past waste stream characterization, which would have proved valuable in configuring chemistry capable of handling the unique stream prior to arrival on site, was not provided. On site, this data was obtained and is contained in Appendix C of the ESTCP Final Project Report(2).

3.3.8 Marine Corps Base Camp Pendleton, CA

The current waste water treatment system in place at MCB Camp Pendleton consists of the following components: burn pits, surface drainage, coalescing plate interceptor separator (the treatment site for ASH Demonstration), and a number of (approximately 90) ineffective oil/water separators that feed large holding tanks.

The specific waste stream treated at MCB Camp Pendleton resulted primarily from wash-rack facilities and was a fuel, oil and grease-contaminated stream. The stream was fed into a coalescing plate oil/water separator from which sludge (settled material), free product (floating material) and effluent water were removed. The particular separator from which source water was taken was functioning quite well, because the influent water was relatively free of surfactant. The specific waste stream characteristics and applicable POTW limits for the waste stream treated during the demonstration were not provided for this site.

3.3.9 Naval Station Pearl Harbor, HI

The current method of treatment for the streams encountered at NS Pearl Harbor is as follows. For O&G contaminated waste streams, fuel/oil absorption pads are used to soak up as much of the free

product from the stream as possible. The water remaining is treated chemically to try to break any emulsion and create a precipitate with the remaining contaminant, which will sink to the bottom of the wastewater container. Water is then decanted from the container. Chemical precipitate and oil/fuel soaked absorption pads are hauled away for off-site treatment and disposal. AFFF contaminated waste is simply disposed of over long periods of time by trickling the waste into the POTW stream at levels such that no discharge limits for AFFF are exceeded.

There were two distinct waste streams treated during testing at NS Pearl Harbor, HI. The first waste stream was not anticipated and was provided at the test site. It was ship's bilge water, which contained fuels, oils and greases along with surfactant and a very small amount of AFFF. Before treatment, it was spiked with additional AFFF. Because this was not an anticipated stream, no waste characterization data or POTW limits were provided.

The second waste stream treated was one generated specifically for testing purposes. It consisted of tap water spiked with AFFF solution. No characterization data was provided or required. This waste stream was treated using two distinct ASH treatment methods, one using a dual polymer system and the second using dual polymer but no coagulating chemical treatment.

3.4 PHYSICAL SET-UP AND OPERATION

The performance of a trailer-mounted 50-100 gpm ASH system was evaluated on various waste streams at each of the nine sites. Each demonstration test consisted of one day of setup, one day of operation, evaluation and sampling, and one day of take down/cleanup. The system is designed to be operated in either a continuous or a batch mode with all activities including set up, testing, sampling and tear down to be accomplished by two technicians with moderate levels of skill.

At all locations the system was operated in either, or both, the continuous feed and batch recirculation modes, depending on influent characteristics and discharge restrictions. Variable feed rate testing of the system took place at some of the demonstration sites to evaluate the system's performance at 50, 75 and 100 gpm. The higher flow rates were evaluated at sites where sufficient volume of waste stream was available to permit reasonable testing periods at the elevated feed rates.

System parameters such as airflow rate, chemical dosages, and defoamer dosages were adjusted to meet the influent flow rate automatically and were adjusted slightly during operation to optimize overall system performance. Typical operating parameters for each site are listed in Table 2. Airflow rates were adjusted during system operation to address any variability in waste characteristics to maximize contaminant removal and control foaming. In addition, defoamer flow rates were also adjusted during system operation to control foaming. Defoamer was used only when absolutely necessary. As demonstrations progressed, operators were able to eliminate usage of defoamer in almost all cases by making alternative adjustments to other system parameters such as airflow rates and sludge discharge rates. Sludge water was also used to spray down the foam in the sludge compartment and short sprays of fresh water were used to reduce foaming in the clarifier compartment. Sludge volume was minimized during the course of the demonstrations through variation of the rate of skimming as well as optimization of the rate and frequency of decanting water from the sludge collection chamber. The optimum dosages of treatment chemicals were determined through jar tests at each of the nine sites prior to commencement of each demonstration.

Initial performance of the full-scale operation determined whether any changes in chemical treatment were necessary.

Typical surface loadings and retention times used for ASH units at various system flow rates are provided in Table 3. These vary depending on waste characteristics and desired effluent purity.

Table 2. Site Specific ASH System Operation Parameters.

Site	Coagulant Type	Coagulant Dosage (ppm)	Flocculent Type	Flocculent Dosage (ppm)	Air Flow Rate (scfm @ 40 psi)	Defoamer Dosage (ppm)
NS Mayport	$FeCl_3$	200	Zetag 7822	60	10-15	100
MCB Camp Lejeune	$FeCl_3$	175	Zetag 7822	60	10-15	0
Tyndall AFB	$FeCl_3$	125	Zetag 7822	80	7-15	25
Goodfellow AFB	$FeCl_3$	129	Zetag 7822	123	5-15	50-100
Tinker AFB	$FeCl_3$ / AE 1125	10 / 15	CE 1159	15	5-15	0
Hill AFB	$FeCl_3$	200	Zetag 7822	100	10-15	0
Edwards AFB	$FeCl_3$	300	Zetag 7822	100	5-15	0
MCB Camp Pendelton	$FeCl_3$	300	Zetag 7822	75	10-15	0
NS Pearl Harbor (O&G and AFFF)	$FeCl_3$	270	Zetag 7822	25	5-15	0
NS Pearl Harbor (AFFF only)	AE 1125	15	CE 1159	15	5-15	0

Table 3. Generalized ASH System Surface Loadings and Retention Times.

	4 Stage ASH Treatment		2 Stage ASH Treatment	
Unit Site	Surface Loading (gpm / ft^2)	Retention time (minutes)	Surface Loading (gpm / ft^2)	Retention time (minutes)
100 gpm	2.2	13.3	4.4	6.7
75 gpm	1.7	18	3.4	9
50 gpm	1.1	26.6	2.2	13.3

3.5 SAMPLING/MONITORING PROCEDURES

Sampling sites include the following: Influent, ASH 1 discharge, ASH 2 discharge, ASH 3 discharge, and ASH 4 discharge (effluent). (Additional samples were taken if the system was

operated in a batch mode and additional ASH stages were used). Samples were clearly marked according to sample location, date and time, and placed in containers suited for the specific type of analyses to be performed. The samples were immediately sealed in individual sampling containers, packed in ice, sealed in a cooler and shipped overnight to the independent laboratory to perform the testing. AFFF samples were separately packed and either immediately analyzed using the foam height measurement method or shipped to personnel responsible for the development of the foam height measurement method.

3.6 ANALYTICAL PROCEDURES

Analyses performed for the demonstrations required no special laboratory capabilities and are routinely performed by many laboratories. A certified and accredited laboratory (Southern Analytical Laboratory, Oldsmar, FL (FL Certification Number: E84129), which has provided consistent, accurate, timely results during past testing, was selected to perform testing on all samples taken at each of the nine demonstration sites. All samples were analyzed for O&G (Method EPA 413.1), TSS (Method EPA 160.2), BOD (Method EPA 405.1), COD (Method EPA 410.4), and TRPH (Method EPA 418.1). BOD and TRPH were conducted on influent, ASH 2 and ASH 4 only. Samples collected from waste streams containing AFFF were also analyzed for AFFF concentration using a Foam Height Measurement technique (refer to ESTCP Technology Demonstration Plan[7] for description). The data collected was analyzed using the analytical methods shown in Table 4.

Table 4. Sampling and Analytical Methods.

Analysis	Analytical Method	MDL	Container	Sample Size	Preservation Technique	Holding Time
O&G	EPA 413.1	2 mg/L	Glass	1 L	Cool @ 4° C, HCl to pH<2	28 days
TSS	EPA 160.2	1 mg/L	Plastic	1 L	Cool @ 4° C	48 hours
COD	EPA 410.4	10 mg/L	Plastic	500 ml	Cool @ 4° C, H_2SO_4 to pH<2	28 days
BOD	EPA 405.1	1 mg/L	Plastic	1 L	Cool @ 4° C	48 hours
TRPH	EPA 418.1		Glass	1 L	Cool @ 4° C, HCl to pH<2	28 days

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4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA

AFFF was analyzed using Foam Height Measurement Technique. A summary of influent and effluent contaminant levels for each site is provided in Table 5. Total percent contaminant reductions for each of the demonstration sites are contained in Table 6. Table 7 shows data quality objectives. Table 8 provides a comparison of available permitted discharge limits for each contaminant along with the corresponding effluent contaminant level achieved at the corresponding site. The O&G limits obtainable for sites where demonstrations were performed were slightly different from the total O&G analyzed in samples. However, for the sake of direct comparison the limits listed in Table 8 for O&G are a combination of the permitted limits for petroleum based and animal based O&G. Detailed laboratory results, on a stage-by-stage basis, are provided for each of the sites in the ESTCP Final Report[(2)].

Table 5. Site Influent and Effluent Contaminant Concentrations.

	NS Mayport	MCB Camp Lejeune	Tyndall AFB	Good-fellow AFB	Tinker AFB	Hill AFB	Edwards AFB	MCB Camp Pendelton **	NS Pearl Harbor (O&G / AFFF Stream)	NS Pearl Harbor (AFFF only Stream)
O&G Influent (ppm)	460	62	80	47,000	3.9	1,300	1,700	110	110	-
O&G Effluent (ppm)	18	44	12	2.1	2.2	10	1,200	NA	44	-
TRPH Influent (ppm)	390	350	33	47,000	0.97	1,800	1,600	NA	88	-
TRPH Effluent (ppm)	95.4	6.0	2.3	4.6	1.1	4.2	1,000	NA	0.8	-
BOD Influent (ppm)	-	81	80	11,000	150	580	4,100	54	110	-
BOD Effluent (ppm)	-	14	15	39	120	160	1,800	NA	49	-
TSS Influent (ppm)	222	550	42	155	44	3,260	210	186	116	-
TSS Effluent (ppm)	51	430	24	5	26	19	84	NA	25	-
COD Influent (ppm)	2,282	986	469	5,384	475	6,044	9,976	89	419	-
COD Effluent (ppm)	1,334	576	97	188	397	305	8,296	NA	213	-
AFFF Influent (ppm)	1,500-2,00	-*	450-500	850	500	-*	-*	-*	250	125
AFFF Effluent (ppm)	<50	-*	<50	<25	<25	-*	-*	-*	<25	<25

* No AFFF in waste stream
** No effluent samples collected due to cross contamination

Table 6. Overall Contaminant Percent Reduction.

	O&G (%)	TRPH (%)	BOD (%)	TSS (%)	COD (%)	AFFF (%)
NS Mayport	96.1	95.4	-	77.0	41.5	97
MCB Camp Lejeune***	29.0	98.3	82.7	21.8	41.6	-*
Tyndall AFB	85.0	93.0	81.3	42.9	79.3	>90
Goodfellow AFB	99.9	99.9	99.6	96.8	96.5	97
Tinker AFB	43.6	0	20.0	41.0	16.5	>90
Hill AFB	99.2	99.8	72.4	99.4	95.0	-*
Edwards AFB	29.4	37.5	56.1	60	16.8	-*
MCB Camp Pendleton**	-	-	-	-	-	-*
NS Pearl Harbor (O&G and AFFF Stream)	96.0	99.1	55.5	78.4	35.8	>90
NS Pearl Harbor (AFFF only Stream)	-	-	-	-	-	>80

* No AFFF in waste stream.
** No samples collected due to cross contamination.
*** Samples not representative of constant feed concentration conditions.

Table 7. Data Quality Results.

Sampling Location	O&G RPD (Limit <13)	O&G LCS % Recovery (Limit 82-144)	O&G LCSD % Recovery (Limit 82-144)	O&G Completeness (Limit >80)	TSS RPD (Limit <22)	TSS MS % Recovery (Limit 77-114)	TSS MSD % Recovery (Limit 77-114)	TSS Completeness (Limit >80)	BOD RPD (Limit <26)
NS Mayport	1.98	100	102	100%	9.52	99	90	100%	-
MCB Camp Leneune	0	85	85	100%	2.93	104	101	100%	2.13
Tyndall AFB	2.88	108	105	100%	5.35	91	96	100%	0
Goodfellow AFB	1.01	99	100	100%	5.29	97	92	100%	7.48
Tinker AFB	2.82	105	108	100%	9.63	98	89	100%	4.26
Hill AFB	2.82	105	108	100%	2.02	98	100	100%	2.25
Edwards AFB	1.0	100	101	100%	0	97	97	100%	11.4
MCB Camp Pendleton	2.0	100	101	100%	3.08	96	99	100%	0
NS Pearl Harbor	2.82	105	108	100%	3.28	93	90	100%	2.91

Table 8. Contaminant Discharge Limit and Effluent Level Comparison.

	NS Mayport*	MCB Camp Lejeune	Tyndall AFB	Good-fellow AFB	Tinker AFB**	Hill AFB	Edwards AFB	MCB Camp Pendleton***	NS Pearl Harbor
O&G Discharge Limit (ppm)	100	Not Available	Not Available	Not Available	300	Not Available	Not Available	Not Available	Not Available
O&G Effluent (ppm)	18	44	12	2.1	2.2	10	1,200	NA	44
TRPH Discharge Limit (ppm)	100	Not Available	Not Available	Not Available	None	Not Available	Not Available	Not Available	Not Available
TRPH Effluent (ppm)	95.4	6.0	2.3	4.6	1.1	4.2	1,000	-	0.8
BOD Discharge Limit (ppm)	250	Not Available	Not Available	Not Available	Report	Not Available	Not Available	Not Available	Not Available
BOD Effluent (ppm)	-	14	15	39	120	160	1,800	NA	49
TSS Discharge Limit (ppm)	250	Not Available	Not Available	Not Available	Report	Not Available	Not Available	Not Available	Not Available
TSS Effluent (ppm)	51	430	24	5	26	19	84	NA	25
COD Discharge Limit (ppm)	None	Not Available	Not Available	Not Available	None	Not Available	Not Available	Not Available	Not Available
COD Effluent (ppm)	1,334	576	97	188	397	305	8,296	NA	213
AFFF Discharge Limit (ppm)****	50	50	50	50	50	50	50	50	50
AFFF Effluent (ppm)	<50	-	<50	<25	<25	-	-	-	<25

* Permitted discharge limits provided for NS Mayport are POTW limits
** Permitted discharge limits provided for Tinker AFB are NPDES permit limits
*** No samples collected at MCB Camp Pendleton due to cross contamination
**** Due to lack of an established AFFF discharge limit, performance criteria for this contaminant was set at the most stringent discharge limit found (50 ppm AFFF)

4.2 PERFORMANCE CRITERIA

The performance objectives for the ASH system were met. The system was able to meet or exceed the performance criteria of reducing O&G and AFFF concentrations to a level below permitted discharge limits in all cases with average removal rates for O&G above 87% and AFFF removal rates greater than 90%. Both contaminants were reduced, in all cases where permitted discharge limits were provided by the site, to levels below the permitted discharge limits for that specific site, thus meeting and exceeding the specified system performance criteria. Flexibility in treatment of varying types of waste streams was also demonstrated. The qualitative objectives such as reliability, automated operation, ease of operation, mobility and versatility were proven at each site and by the ease with which the system was moved to, and used on, such a wide variety of waste streams with little to no performance problems throughout testing.

4.3 DATA QUALITY OBJECTIVES

It was the responsibility of the analytical laboratory to perform matrix spike (MS) and matrix spike duplicates (MSD), lab control samples (LCS) and lab control sample duplicates (LCSD) as well as perform calculation of surrogate recovery for MS, MSD LCS and LCSD for determination of

percent recovery (accuracy), relative percent difference (precision), and completeness in accordance with their established quality assurance/quality control (QA/QC) practices. Results of these quality controls (RPD, % Recovery and Completeness) are found in Table 7. As can be seen from these results all the data quality objectives for precision, accuracy and completeness in all cases were met. This technique involves the development of matrix spikes at varying concentrations to generate an established concentration curve against which field samples were compared. In addition field duplicates and blanks were taken to ensure data quality was acceptable and accurately represented the samples taken during testing. Standard MS, MDS, LCS LCSD were not used during AFFF measurements.

Representativeness in samples was ensured through the sample collection, handling, preservation and shipping activities according to approved operating procedures and protocols. Any deviations from established guidelines were due to outside issues during testing and are recorded and explained in Section 4.4. Comparability of sampling events was the final quality objective to be addressed. The application of standardized sampling and analytical procedures ensures comparable data. Standard units, standardized report formats, consistent quantitative calculations per approved methodologies, and standardized statistical approaches were used and provided in results determined through the project analytical laboratory and therefore ensured comparability.

4.4 DATA ASSESSMENT

Assessment of the data collected from all three demonstration regions (East Coast, Mid-Continent and West Coast) indicates that the system demonstrated consistent O&G removal rates of >85 % and as high as 99% (This does not include results from MCB Camp Lejeune, which did not have constant feed concentration, and Edwards AFB, which was ineffective due to VOC contamination). The reduction percentages are particularly impressive in the instances where very low concentrations of O&G were present in the influent. This oil is typically the most difficult to remove from a waste stream and even in cases where almost no O&G was present (such as Tinker AFB), reduction of over 40% was still possible. The system also demonstrated tremendous success in the removal of AFFF from the waste streams in which it was present, even in significant concentrations such as NS Mayport and Goodfellow AFB. During testing at NS Mayport, the system was exposed to AFFF concentrations much higher than the system had ever experienced before. With minor adjustments to system operational parameters, such as air flow rate and clarifier level, the system was able to reduce the AFFF concentration by 97% from these extreme concentrations to a concentration below permitted discharge limits (<50 ppm AFFF) in 12 stages of ASH treatment. At Goodfellow AFB the system was able to reduce the AFFF concentration from 850 ppm to below 25 ppm in fewer than 4 stages of ASH treatment, reducing AFFF concentration by 97%, while being operated in the batch recirculation mode. While operating in the feed mode the system demonstrated AFFF removal rates > 90% with only the initial four stages of ASH treatment.

The remaining data from these tests, upon assessment, demonstrates fairly significant reductions in other waste stream contaminants including TRPH (average 97% reduction), TSS (average 73% reduction), BOD (average 58% reduction) and COD (average 49% reduction). These results demonstrate the system's capability to enhance the waste stream quality beyond the primary concern of O&G and AFFF removal. While the reductions in these other parameters are somewhat dependent on the individual waste stream, the ASH system provided an appreciable reduction in the concentrations of these contaminants in every case for which analyses were performed.

The flexibility and ease with which the system was set up, operated and torn down without encountering any physical operational problems throughout the nine site demonstrations proved the system's ease of operation and showcased its automated operation as well as its water treatment capabilities. The testing also allowed for system limitations to be established. The limits established included overall source O&G concentration of 20,000 ppm and AFFF concentration of 2,000 ppm.

Explanations of any unique occurrences at each of the demonstration sites are included below.

4.4.1 Naval Station Mayport, FL

The high concentration of AFFF in the stream at NS Mayport and the excessive foaming associated with those levels necessitated the adjustment of some operating parameters to control foaming during batch recirculation operation. Adjustments made included addition of defoamer, the dropping of overall system level and reduction of airflow volume to minimize excessive foaming. Each batch was initially processed at 50 gpm until foaming became controllable, after which the processing was performed at 75 and 100 gpm flow rates to speed the processing time. Periodic testing of the final ASH stage (stage 4, 8, or 12) was performed to indicate when effluent levels fell under discharge limits.

4.4.2 Marine Corps Base Camp Lejeune, NC

Testing was stopped when Base personnel informed ASH operators that once the level in the discharge location had reached a given height, the discharge for the system became cross-connected to the influent location. This level had been reached and the system had, for approximately 20 minutes, been pulling influent cross-contaminated with effluent. At that point the system was immediately shut down. It was determined that only the water contained in the ASH 4 discharge did not include cross-contaminated water because the time required for the entire system to be cross-contaminated would have been approximately 34 minutes (at 50 gpm). Samples were therefore only taken at ASH 4. Influent samples were taken from a composite taken over the length of the test run. It therefore contained some cross-contaminated water, but samples were drawn regardless to provide a baseline against which to compare the ASH 4 results. The exception to this was the influent O&G sample. Sufficient volume of the true influent, for that sample, had been collected prior to cross contamination. Because cross contamination had not reached stage 4 of the ASH system and the composite influent sample contained very little cross contaminated influent, the resultant removal rates were used in determination of overall system effectiveness.

4.4.3 Tyndall Air Force Base, FL

Treatment at this site took place without any unique circumstances requiring explanation.

4.4.4 Goodfellow Air Force Base, TX

The particular waste stream treated at Goodfellow AFB was water accumulated during fire-training exercises. The volumes accumulated range from 20,000 - 40,000 gallons during a 5- to 6-hour training period and so testing at Goodfellow AFB was originally intended to provide a better evaluation of the ASH system's operational capabilities under extended run-time conditions. However, this was not possible due to training schedules and the configuration of waste treatment

operations. The available waste stream volume was limited to what was contained in the oil/water separator (< 10,000 gallons), which allowed only a few hours of run time over the course of two days. In addition, the Base made no provision for storage or disposal of sludge from the system. Sludge generated had to be returned to the separator from which system feed was being taken. This meant that the system could only be run until the onboard sludge tank was full. Otherwise the sludge being dumped to the separator would have cross-contaminated in influent water. The liquid accumulated in the sludge chamber was systematically discharged to the pumps feeding the storage tank and only solids were maintained in the sludge compartment. This still limited the volume that could be processed through the system due to the 500-gallon capacity of the sludge compartment.

4.4.5 Tinker Air Force Base, OK

Bench scale testing was conducted in-house at Kemco Systems to determine initial estimates of chemical dosing which would be required during this demonstration. Testing determined that, due to a lack of O&G contaminants, a different chemistry would be required for the treatment of the stream. Typically a coagulant is used break O&G emulsion and a cationic flocculent is used to agglomerate the O&G. In that process a small percentage of the AFFF contained in the waste stream is trapped in the floc. The remaining AFFF is removed via aeration. This waste stream however, contained no O&G with which the floc could be formed. Due to this fact, it was necessary to incorporate the use of an anionic polymer followed by a cationic polymer. The two polymers join, forming a floc, which accomplishes the task of trapping a small percentage of the AFFF, thus allowing the remaining AFFF to be more easily removed through aeration.

4.4.6 Hill Air Force Base, UT

The waste stream source provided for demonstration purposes at Hill AFB was from an oil/water separator fed by steam cleaning operations for engines. Said to contain 3,000 gallons, it would have provided sufficient volume to fill the system (1,700 gallons) and still run the system in a feed mode during the actual demonstration. Upon arrival on site, it quickly became evident that the volume provided was only about 800 gallons. Therefore, water from the source (600 gallons) was pumped from the oil/water separator into the sludge tank on board the ASH trailer. This allowed the oil/water separator to be re-filled to 800 gallons. The ASH system wastewater feed pump was used to circulate the water between the sludge chamber and the oil/water separator to obtain a consistent waste stream. This combined volume equaled 1,400 gallons of wastewater, which provided a volume sufficient to almost completely fill all four chambers of the system. Bench scale testing was conducted to establish the required chemistry for stream treatment. In order to bring the system up to full capacity, following sampling, an additional 300 gallons of fresh water was added equally to each of the four-clarifier chambers, and brought the total volume up to approximately 1,700 gallons.

After filling the system, recirculation mode without chemical treatment was used for the demonstration. It was discovered that a small amount of polymer should have been (but was not) introduced into mix chamber two for two minutes in order to complete the chemical treatment of the volume in mix chamber one (which only received ferric chloride) at the end of the feed cycle. O&G de-emulsified by the ferric chloride addition in mix chamber one remained in the system resulting in O&G residue on walls and cross contamination of clean waters with this residue during recirculation. As a result, treated effluent resulting from recirculation operation was poorer than

obtained during feed mode operation. This occurrence led to an understanding of the need for some additional chemical treatment upon initiation of recirculation operation.

4.4.7 Edwards Air Force Base, CA

On-site bench scale testing provided information showing that the waste stream was not typical of any other DoD waste stream that had been encountered. It would not respond effectively to the typical DoD chemical treatment regime consisting of a coagulant (ferric chloride) and cationic polymer (Zetag 7822). Differing chemical treatments were investigated with the limited number of chemicals available on board the ASH system trailer. None of the treatments provided positive results. The sources feeding the tank from which influent was taken included a large number of activities from various operations all over the Base. These included parts cleaning operations, motor pool and wash rack facilities and solid waste de-watering as well as other operations. Waste characterization data for similar waste streams were obtained from past experiences. This data showed that the waste stream contained high concentrations of many volatile organic compounds, especially benzene, naphthalene and derivatives, which are typically found in industrial strength solvents used for parts cleaning. These contaminants emulsify O&G contaminants in such a way that they are not readily removed by typical ASH chemistry treatment. The means by which such a stream should be treated would be to perform VOC stripping to drive off volatile and semi-volatile contaminants, after which standard chemistry and ASH treatment could prove effective. However, in this instance, VOC stripping was not an option. A "best" chemical treatment, given the available chemicals, was developed. The stream was re-circulated through the ASH system for 8 additional stages (with the hope that air sparging would strip some of the VOCs from the stream). The stream was then chemically treated a second time and processed through 4 stages of ASH treatment to try to remove any additional O&G contaminants freed from emulsion after some VOCs were driven off.

4.4.8 Marine Corps Base Camp Pendleton, CA

Testing conducted at MCB Camp Pendleton involved a waste stream for which two representative samples had been provided. One sample was of the water present in the coalescing plate separator and the other a sludge (settled material) sample from the same separator. The volume ratio of water to sludge in the separator was given as 7:1 water to sludge. In-house testing performed at Kemco using this ratio cleaned up the waste stream very nicely.

Due to lack of total volume available, there was no pre-demonstration full-scale run permitted. On demonstration day, the influent became very dark and treatment proved ineffective. Attempts were made to change the location of the suction point in hopes that influent would become more acceptable but this was not achieved. Operation personnel began investigating the source to find that the entire volume remaining in the separator was primarily sludge. It was later discovered that the original volume had been approximately 50% water and 50% sludge, not 12.5% sludge as had been anticipated. Sludge is usually removed from the separator on a monthly basis but had not been removed for over two months, thus explaining the overabundance of sludge volume. Further processing was useless and there was no possibility for sampling of the system.

4.4.9 Naval Station Pearl Harbor, HI

Bench scale testing of the first waste stream source (ships' bilges and AFFF) was performed on site to determine required chemical dosing. A pre-demonstration full scale run was performed with four stages of feed followed by four additional stages of batch recirculation with no chemical treatment. During demonstration, the same procedure was followed for a second batch from which samples were pulled. The second waste stream source was generated on site for system testing purposes. This stream consisted of 5,500 gallons of tap water spiked with AFFF. The intent of this testing was to compare the system's ability to remove AFFF from an AFFF-only waste stream by two different dual polymer treatment methods: the first being dual polymers in combination with ferric chloride coagulant (the treatment used at Tinker AFB), the other being polymers only without ferric chloride coagulant (which was the treatment on this second waste stream at NS Pearl Harbor).

4.5 TECHNOLOGY COMPARISON

See the advantages listed in Section 2.4 of this report.

5.0 COST ASSESSMENT

5.1 COST REPORTING

The ASH treatment system is designed to be a mobile means of effectively treating a variety of waste streams at different sites within a given DoD installation. The costs associated with the operation of the system are reported in Table 5-1 as a function of the activities and expenditures associated with the implementation of the system, on a temporary basis, at a single treatment location. They are based on the costs incurred from use of the system, in full scale for demonstration purposes, with the exception of costs associated with laboratory analysis, and these are the costs that are expected for routine use. Laboratory costs for demonstration purposes were more extensive due to the need to sample from multiple system locations for evaluation and improvement of system performance. Costs are provided for the operation of the system at a flow rate of both 50 gpm and 100 gpm (where applicable) and on a per volume basis. These costs assume that the system is operated at a single flow rate throughout treatment and that a typical treatment day is eight hours in length. All costs are based on operation of a full scale system and there is therefore no need for extrapolation.

The expected costs for the ASH system can be broken down into three distinct categories. "Startup" which includes those costs associated with the transportation of the system to a specific treatment site and the initial bench scale chemistry testing, system unpacking and connection required to ready the system for use. "Operation & Maintenance" includes the costs associated with the system as it operates during the treatment process at the specific site. Finally, "Demobilization" includes the costs involved in system shutdown, clean up, pack up and transportation to a holding area or next treatment location. In summary, the predicted operational costs for the system are dependent on the stream-specific contamination characteristics. The range of actual operational costs (excluding labor costs associated with the set up, operation and monitoring of system operation and system tear down) for the contaminant levels encountered during demonstration testing ranged from $0.17/1,000 gallons treated (AFFF treatment with no chemical treatment) to $2.54/1,000 gallons treated (for extremely high O&G concentration). This operational cost range included only the cost of consumables and utilities. Details of the basis of the numbers used in determining this range can be found in Table 9 with subsequent explanatory notes.

Notes:

1. Startup "Labor" to include the man-hours required for transport of system to a treatment site on base, determination of site specific chemistry, system unpack, connection of system utilities and connection of system influent and effluent lines.

2. Capital equipment costs were not included because they are highly variable and depend on the specific application of the ASH system (see Section 5.3 of this report).

3. Operation and Maintenance "Labor" and "Monitoring" to include man-hours required for the operating personnel to operate system equipment, collect samples, and monitor system performance through a 4-stage flow.

Table 9. Cost Summary by Category.

Startup		Operation & Maintenance			Demobilization	
Activity	**Man-Hours**	**Activity**	**Cost or Man-Hours per 1,000 gallons treated @ 50 gpm**	**Cost or Man-Hours per 1,000 gallons treated @ 100 gpm**	**Activity**	**Man-Hours**
Labor	8 (See Note 1)	Labor	0.33 man-hr (See Note 3)	0.17 man-hr (See Note 3)	Removal of Equipment and Structures	12 (See Note 11)
Planning & Contracting	NR	Monitoring	0.33 man-hr (See Note 3)	0.17 man-hr (See Note 3)	Site Restoration	NR
Site Preparation	NR	Analytical Services	$145 (See Note 4)	$145 (See Note 4)	Decontamination	NR
Capital Equipment	Not included (See Note 2)	Equipment or Facility Modifications	NR	NR	Demobilization of Personnel	2 (See Note 12)
Construction	NR	Utilities	$0.17-$0.37 (See Note 5)	$0.3-$0.55 (See Note 5)		
Permitting & Regulatory Requirements	NR	Training Required to Operate Equipment	Not Included (See Note 6)	Not Included (See Note 6)		
		Effluent Treatment and Disposal	$0.00 (See Note 7)	$0.00 (See Note 7)		
		Residual Waste Handling and Disposal	Not Included (See Note 8)	Not Included (See Note 8)		
		Ancillary Equipment	$0.00 (See Note 9)	$0.00 (See Note 9)		
		Consumables & Supplies	$0.00 [no chemical treatment]	$0.00 [no chemical treatment]		
			$0.66-$2.17 [liquid coagulant and flocculant]	$0.66-$2.17 [liquid coagulant and flocculant]		
			$0.21-$0.55 [Dry coagulant and flocculant]	$0.21-$0.55 [Dry coagulant and flocculant]		
			$0.97 [Dual liquid polymers with liquid or dry coagulant]	$0.97 [Dual liquid polymers with liquid or dry coagulant]		
			(See Note 10)	(See Note 10)		

NR = not required

4. Analytical costs are based on the cost of a typical single sample set, routinely performed for a given treatment site. The costs include funds for one set of analyses (to be performed on the system effluent to insure acceptable discharge quality) including O&G, TPH, TSS, BOD and COD. Not included in this estimate is the cost associated with AFFF analysis. It is anticipated that operation personnel will perform analysis on site. The initial capital cost for the test equipment is estimated at $500 and a set of AFFF tests for influent, and four ASH

stages would require 6-8 man-hours and could be incorporated into the system monitoring man-hours.

5. Utility costs on the high end of the ranges listed include those associated with the operation of the primary system equipment including Air Compressor (operating 53% of the time during 50-gpm treatment and 100% of time during 100-gpm treatment), ASH 1 - ASH 4 pumps (assumed to be in continuous operation once system has reached operating levels), Discharge Pump (operating 49% of the time during 50-gpm treatment and 100% of time during 100-gpm treatment). Energy costs were estimated as $0.09/ kWh. The low end of the range listed is achievable with a system change discovered during system demonstration testing. The volume of air required for the ASH modules can be supplied by a 3.5 HP blower (rather than a compressor). This alteration would still require the use of a smaller (5 HP) compressor for operation of the sludge pump and air pressure level sensors, but the overall utility cost savings for the operation of this equipment vs. the 20 HP compressor is significant, as can be seen from the utility cost range.

6. Training costs were not included here because the costs discussed are based on the expenditures associated with the application of this system to a single treatment site. It is anticipated that the personnel trained on the operation of this system would operate the system during a wide range of activities and thus the one time training cost should not be applied to a single site application.

7. It is anticipated that effluent will be treated to below permitted discharge limits, making it permissible to release it to the existing wastewater treatment system in operation at the facility resulting in no additional cost.

8. The costs associated with the further treatment and/or disposal of residual waste are not detailed here because these costs will be site dependent and variable (see Section 5.3 of this report).

9. This cost estimate is based on the fact that the majority of DoD sites have generators available for use and thus no ancillary equipment cost would be incurred for the treatment. However, if rental of a generator were required the costs would be based on a generator rental cost of $100/day with the anticipated work day lasting 8 hours, during which 24,000 gallons of waste water could be treated if operating at 50 gpm and 48,000 gallons if the system were operated at 100 gpm.

10. Consumables and supplies include treatment chemicals (coagulant [ferric chloride], flocculent [polymer] and defoamer). Ranges given are for the best and worst case scenarios for the use of each chemical at both 50 gpm and 100 gpm operation of the system. Costs for the polymer and the coagulant are determined based on use of both liquid and dry versions of the chemical. In addition, a costing for the non-O&G waste streams with both no chemical treatment and dual polymer treatment case is also provided. It must be noted that the use of dry chemicals in any of these cases would require increased man hours for preparation of chemicals for use by the system and additional capital costs for mixing containers and mixing equipment required. Costs used for each of the chemicals are based on bulk purchase (typically between 55 and 275 gallons required). The cost of the pH adjustment chemicals are not included here. pH adjustment was required at only one

demonstration site. This was necessitated by the manner in which the water was used (closed loop) and would not be typical for most DoD sites. In the instance where this pH adjustment was required, 1,000 ppm of a 20% solution of muriatic acid was used. On a large scale, this could provide a significant increase to the overall chemical cost. In the event that this pH adjustment is required, it is suggested that 93 Baume sulfuric acid be used at 200 ppm instead of the muriatic acid, thus reducing the pH chemical cost from $2.00/1,000 gallons of water treated with the muriatic, to $0.32/1,000 gallons treated with the sulfuric acid.

11. Costs include man-hours required for the pump out and drain of system, clean up and flushing of system equipment (to prevent cross contamination between sites), the disconnection of system utilities, influent and effluent lines and the packing up of system equipment.

12. While there should really be no demobilization of personnel, there will be man-hours required for removal of system from the treatment site and transport of the system to a holding area or the next treatment site. The costs associated with this transport are included.

5.2 COST ANALYSIS

The initial capital expenditure for the system may change dramatically depending on the type(s), number and volume(s) of waste streams, contaminant concentrations, options such as remote monitoring control systems, current treatment methods and the costs associated with those methods, which vary from site to site For general capital cost reference, a system-costing chart (July 2002) is provided as Table 10. Total life cycle of equipment is dependent on its application, environment and use, thus, making the projection of a life cycle extremely variable. Costs associated with initial personnel training for the operation of a system are incorporated into the initial capital cost of the system, with training to be conducted by representatives of the system manufacturer. Additional training of new or different personnel after the completion of initial training will be the sole responsibility of the site at which the system is employed.

Table 10. ASH System Capital Cost Approximation.

		Costs in addition to Base System Cost			
System Flow Rate	**Base System Cost***	**4 Stage System**	**Monarch Controls**	**Trailerized System**	**AL6XN Steel Construction**
50 gpm	$173,000	$20,090	$15,000	$24,000	$30,000
100 gpm	$194,350	$24,382	$15,000	$24,000	$45,000
150 gpm	$224,250	$35,090	$15,000	$24,000	$65,000

*Base System Includes:

- Feed pump and flow meter
- Chemical reaction tank (3 compartments with mixers)
- ASH feed pumps
- ASH clarifier and skimmer assembly for 2-stage system
- Sludge pump
- Recirculation / clearwell discharge pump
- Chemical tanks (3)
- Chemical metering pumps (3) and pre-dilution system
- Blower (to provide ASH module air flow)
- Skid mounted and packaged system
- 304 stainless steel construction
- Operation / Maintenance Manual
- 1 Week on-site start up training

5.3 COST COMPARISON

At the present time, there is no other existing or competing treatment method available for the effective removal of both AFFF and O&G materials from a waste stream. Kenterprise, Inc, under a Phase I SBIR contract, did provide a bench scale chemical membrane unit capable of removing AFFF from a waste stream, resulting in a significant reduction in foaming. However, under a Phase II effort, the mobile system fabricated did not prove, during several demonstration attempts, to be able to effectively remove both AFFF and O&G contaminants. Because the ASH system has been the only technology proven capable of AFFF and O&G treatment of a waste stream, it is not possible to accurately compare the costs associated with the ASH system directly to any other technology. The current system used most widely at DoD sites for waste stream treatment is the conventional oil/water separator. This technology, however, is stationary, and is capable of removal of O&G products only. Therefore a cost comparison between the mobile ASH system (with the benefit of AFFF removal capabilities) and the most common existing treatment would be inappropriate.

One comparison, which should, however, be considered, is between the costs associated with ASH treatment of a waste stream (and the disposal of any residual wastes generated during operation) versus the costs incurred for the off-site treatment of the same waste stream. Because there is no other means of effectively removing AFFF from a waste stream, typically the entire volume of the stream must either be stored indefinitely or removed for off-site treatment at significant cost to the site (off-site treatment costs will vary from location to location). This significant cost is incurred because of the large volume requiring treatment and the inability of conventional methods to separate the AFFF from the stream. The ASH system can, however, effectively remove the AFFF from the stream, such that the volume required for storage or off-site treatment is typically about 7% of the total volume of water treated.

For the nine sites visited, only three sites (NS Mayport, Edwards AFB and NS Pearl Harbor) were willing to provide data on current cost of off-site disposal of wastes. The off-site treatment costs provided for these sites were $0.82/gallon (~.$0.10/pound if waste is approximately the density of water), $0.14/pound and $0.32/pound respectively, which provides an average cost $0.18/pound treated. Based on the off-site treatment costs and volumes provided by participating installations and the estimated capital and operating costs for a base system with adder for 4 stages, it is possible to calculate a very approximate payback for the ASH system. It should be duly noted that this payback is only a basic approximation. Payback for a specific site will be dependent on many factors including site-specific waste stream characteristics, contamination levels, flow volumes, desired effluent contaminant levels and current disposal costs.

Estimated payback examples are provided for both an O&G stream and an AFFF stream. Tyndall AFB provided a prime example of an O&G stream while NS Mayport provided a stream containing high AFFF concentrations as well as some O&G. Both sites were also able to provide current off-site treatment costs as well as volumes requiring off-site treatment.

Capital costs used in the payback examples include equipment cost only and do not include any facility construction costs to house the system. Operational costs used included labor for system operation and monitoring as well as cost of system utilities and consumables (treatment chemicals and defoamer). Labor costs are estimated at $15/man-hour for technician level personnel with an additional $15/man-hr for overhead. The utility and consumables costs included are based on the

treatment concentrations encountered during site testing, and on the dosing rates and system operational parameters required to treat the stream. The actual numbers were adjusted to a 100 gpm system. Utility costs include the costs for operation of system's primary energy consuming components including pumps, blower (for provision of ASH air) and compressor for operation of sludge pump and system level controls. The minimal energy consumption of system controls and chemical feed pumps was not included. Costs for consumables (treatment chemical and defoamer) are based on the levels required during demonstration testing, representative of those expected in the full-scale operating scenarios.

5.3.1 Payback Approximation for NS Mayport

- Stream Characteristics: High AFFF concentration, moderate O&G concentration.

- Utility costs are based on operation of the system in a batch mode, such that each 1,800-gallon batch is send through the system 3 full times providing 12 stages of ASH treatment (required for high AFFF concentrations). Assumes ASH pumps, discharge pumps and blower operate continuously during operation and compressor operates 10% of time during system operation.

- Consumables Costs reflect dosage required for initial pass through only (stages 1-4). No chemicals are required for stages 5 - 12. Costs for chemicals assume bulk purchase of chemical for use by installation.

- Sludge Disposal Costs are based on disposal of a volume equal to 6% of total system throughput at the provided off-site disposal cost.

- Capital Cost is taken directly from Table 10 for 100-gpm base system with adder for 4 stages.

- Treatment Dosage: Coagulant ($FeCl_3$) = 200 ppm, Flocculent (Zetag 7822) = 60 ppm.

- Off-site disposal cost = \$0.82/gallon.

- Annual off-site treatment volume: 115,200 gallons (~8% of annual bilge water volume of 120,000 gallons).

- ASH operation time required to treat volume through 12 stages : 57.6 hours / year.

- ASH sludge off-site treatment volume: 6,912 gallons (6% of total system throughput).

- Treatment Chemical Cost: Coagulant - \$ 3.12/gal , Flocculent: \$1.29/lb (\$10.90/gal).

- **Capital Cost:** \$218,732
  - Base System: \$194,350
  - 4 Stage Adder: \$ 24,382

- **Annual Operational Costs for ASH System:** $3,717
  - Labor: $3,456
    Operation: 57.6 hr/year x $30/hr ($15/hr labor + $15/hr overhead) = $1,728
    Monitoring: 57.6 hr/year x $30/hr ($15/hr labor + $15/hr overhead) = $1,728
  - Utilities: 115,200 gal x $0.99/1000 gal (through 12 stages) = $114
  - Consumables: Coagulant - $ &72/yr, Flocculent - $75/yr, Total = $147

- **Sludge Disposal Costs:** 6,912 gal/year x $0.82/gal = $5,668/year

- **Current Annual Off-Site Disposal Costs:** 115,200 gal x $0.82/gal = $94,464/year

- **Annual Cost Savings:** $94,464 - $9,385 = $85,079

- **Estimated Payback Period:** Capital Cost/Annual Cost Savings
  $218,732 / $85,079 = **2.6 years**

5.3.2 Payback Approximation for Tyndall AFB

- Stream Characteristics: Low AFFF concentration, moderate to high O&G concentration.

- System trailerized to handle multiple treatment streams within installation. Two streams considered for payback estimation were both O&G based streams.

- Utility costs are based on operation of the system in continuous feed mode. Assumes ASH 2-4 pumps, and blower operate continuously during operation ASH 1 and Discharge pumps operate ~50% of time and compressor operates 5% of time during system operation.

- Consumables Costs reflect dosage required for stages 1-4. Costs for chemicals used assumes bulk purchase of chemical for use by installation.

- Sludge Disposal Costs are based on disposal of a volume equal to 6% of total system throughput at the current off-site disposal cost.

- Capital Cost is taken directly from Table 5-2 for 50-gpm base system with adder for trailerization.

- Treatment Dosage: Coagulant ($FeCl_3$) = 200 ppm, Flocculent (Zetag 7822) = 100 ppm.

- Treatment Chemical Cost: Coagulant - $ 3.12/gal , Flocculent: $1.29/lb ($10.90/gal).

- Off-site Disposal Cost: Stream 1 = $0.32/gallon, Stream 2 = $0.62/lb.

- Annual off-site treatment volume: Stream 1 = 91,000 gallons, Stream 2 = 1,145 lb (~91 gallons based on a sludge density equal to 1.5 times the density of water), Total = 91, 091 gallons.

- ASH operation time required to treat volume through 4 stages: Stream 1 = 30.3 hours/year, Stream 2 = 0.1 hours/year, Total = 30.4 hours/year.

- ASH sludge off-site treatment volume: Total = 109 gallons (6% of total system throughput) [Costed at $0.32/gallon due to large percentage of stream 1].

- **Capital Cost:** $197,000
  - Base System: $173,000
  - 4 Stage Adder: $24,000

- **Annual Operational Costs for ASH System:** $1,996
  - Labor: $1,824
    Operation: 30.4 hr/year x $30/hr ($15/hr labor + $15/hr overhead) = $912
    Monitoring: 30.4 hr/year x $30/hr ($15/hr labor + $15/hr overhead) = $912
  - Utilities: 91,091 gal x $0.17/1000 gal (through 4 stages) = $15.50
  - Consumables: Coagulant - $ 57/yr, Flocculent - $99/yr, Total = $156

- **Sludge Disposal Costs:** 109 gal/year x $0.32/gal = $35/year

- **Current Annual Off-Site Disposal Costs:** $29,830/yr
  - Stream 1 = 91,000 gal x $0.32/gal = $29,120/yr
  - Stream 2 = 1,145 lb x $0.62/lb = $710/yr

- **Annual Cost Savings:** $29,830 - $2,031 = $27,799

- **Estimated Payback Period:** Capital Cost/Annual Cost Savings
  $197,000 / $27,799 = **7.1 years**

6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

The key factors that affect costs associated with this technology are primarily site-specific. Volume and frequency of treatment required will affect capital costs to provide a unit of sufficient size, flow rate and overall capabilities. Utility costs associated with the system used for demonstration purposes were primarily due to by the 20 hp air compressor used to supply air to level control, sludge pump and ASH units. Future models should incorporate the use of a regenerative blower to provide ASH airflow, which would allow a smaller, 5hp, compressor to be installed to provide high-pressure air and to power the sludge pump. This change would cut energy costs for the system approximately in half. The type and concentrations of contaminants in a waste stream will also affect the required chemical regime and required treatment times. High concentrations of AFFF may require as many as 12 stages of treatment. The system has a relatively low maintenance load and cost because there are very few moving parts. Components requiring maintenance include the pumps and the skimming system, all of which use off-the-shelf parts. The unit is flushed upon completion of a stream treatment.

Payback for the use of an ASH system can vary dramatically based on many factors including stream type, system chosen and most importantly, on volumes to be treated. In both example cases, the ASH system described would only be used for a very short period of time each year to treat the current estimated of- site treatment volumes. In cases where the system would be used on a more regular basis the payback would be significantly faster than the results shown. However, even with very limited use, as is the case at Tyndall AFB and NS Mayport, the payback period is reasonable given the life expectancy of the equipment.

6.2 PERFORMANCE OBSERVATIONS

The ASH system proved to be extremely effective at the removal of O&G and AFFF, which was the primary performance objective of the testing. Average contaminant reductions exceeding 87% were achieved in all cases, including O&G only, AFFF only, and O&G/AFFF waste streams. Average O&G removal was >87% and AFFF percent reduction averaged >90% with all discharge concentration below 50 ppm AFFF.

Secondary performance criteria, which included demonstration and evaluation of the system's versatility and ease of use, were also demonstrated. The only periods of poor performance of the ASH unit were due to either a waste stream that contained contaminant(s) or contaminant levels that the system was not designed to handle (high VOC concentration, excessive sludge concentration) or from lack of facilities (insufficient volume, no discharge location, no sludge containment allowances). However, each of these instances provided insight into the system and its requirements. Overall system performance exceeded expectations and cemented the technology as a valuable tool available for DoD sites for the treatment of previously untreatable or troublesome waste streams.

6.3 SCALE-UP

The unit used for demonstration purposes was a full-sized unit. Consequently, there should be no issues for scale-up of the technology.

6.4 OTHER SIGNIFICANT OBSERVATIONS

At this time no other significant factors should affect the implementation of this technology.

6.5 END-USER ISSUES

Implementation of the system into DoD sites has already begun with the delivery of a 50-gpm, 2-stage, trailerized system to Naval Station Mayport, FL by Concurrent Technologies Corporation (CTC). For implementation at other sites, contact the DoD project officer (listed in Appendix A) or direct inquiries about system design to the system manufacturers, Kemco Systems, Inc., Clearwater, FL by contacting the project Principal Investigator listed in Appendix A.

There are over 2,000 military installations throughout the US. Many, if not all, must deal with treatment of waste streams containing either O&G, AFFF or both. These installations could significantly benefit from the incorporation of the ASH technology.

6.6 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

Government regulations concerning the quality of water discharged from a facility exist on three basic levels: federal, state and local. The regulations have been developed and implemented under the Clean Water Act and administered by the US Environmental Protection Agency (EPA), at the federal level. Water releases from military installations throughout the U.S. are typically regulated by the local water treatment district to which their effluent is released. Typically, oils and greases are regulated in order to prevent fouling of sewer collection systems and treatment works. Fuels and AFFF are regulated due to their toxicity, ability to interfere with the operation of the treatment plants and their potential impact on surface waters. Each local district will maintain their own contaminant limits based on regulations for effluent release quality. For example the Hampton Roads Sanitation District in Norfolk, Virginia prohibits the discharge of wastewater contaminated with AFFF into its plant unless the AFFF concentration is less than 50 ppm. Although individual limits for sites will vary, there is an overall need at most sites to minimize the contaminant concentrations released. The ASH system provides a means for reducing levels of such contaminants, for which restrictions are set in most local water districts, including O&G and AFFF.

Following ASH treatment, waste in the form of sludge and concentrated contaminant- (POL products, AFFF) rich wastewater (in small volumes) will remain. Independent testing at Goodfellow AFB showed that this material was non-hazardous, even at very high contaminant concentrations, based on RCRA criteria.

In the case of AFFF, the manufacturer (3-M) has provided assurance that under no conditions is the AFFF considered a hazardous material[8]. The amount of butyl carbitol in AFFF varies from manufacturer to manufacturer. Also, the test sites' waste streams vary in concentration of AFFF. Therefore, it is difficult to predict the amount of butyl carbitol present in the waste sludge. In any case it is believed that the butyl carbitol in the sludge generated by the ASH system would be less than 20 part per million (ppm). This sludge can therefore be returned to the site's waste treatment system. This treatment should be carried out according to the individual site's pre-existing local, state and federal (RCRA) waste management plan prior to any release.

It is anticipated that the level (concentration) and mass (pounds) emissions arising from the demonstrations will be at *de minimus* levels. Emissions will be non-existent or below the levels for regulation under VOC or air toxic guidelines. Emission testing was performed during the ASH system operation by the Bioenvironmental Engineering group of Tyndall AFB and was sampled using a Myran vapor analyzer. The instrument is capable of discerning a wide variety of airborne chemicals. No hazardous emissions were detected. Specifically benzene, toluene, ethyl benzene, and xylenes (BTEX) were targeted. Additionally, carbon monoxide and carbon dioxide measurements were taken. Some levels of carbon monoxide were found but not in excess of the Air Force Occupational Exposure Limits (OELs). In the event that a stream to be treated using the ASH system is highly contaminated with VOC constituents, the stream should be processed through VOC stripping prior to ASH treatment to minimize the release of VOCs to the atmosphere during the aeration that occurs during the ASH operation.

While there are no specific POTW restrictions on the discharge of AFFF, regulations typically include general prohibitions on discharges that cause upsets or interferences with the operation of the POTW. Excessive foaming, which may be caused by AFFF if released to the POTW, would fall under such a prohibition. For this reason the release of AFFF must be limited and the ASH system has proven to be an effective means for accomplishing this removal.

Finally, in addition to other testing, noise dosimetry for the operating ASH system was recorded during operation at Tyndall AFB. Dosimetry levels were averaged over an eight-hour time frame and found to exceed the Air Force OEL of 85 dBA. It is therefore required that hearing protection be required when operating the ASH system. It should however be noted that the majority of noise generation resultant from the operation of the ASH system is caused by operation of the system's 20 hp compressor. All subsequent ASH systems will no longer use this method of air generation but rather a small regenerative blower and a much smaller compressor from which noise levels will be dramatically reduced.

6.7 LESSONS LEARNED

Operational lessons learned from demonstration testing include the following.

- Pre-treatment waste stream characterization is extremely important to insure that system chemistry is properly adjusted to handle the waste stream at hand. On-site jar testing of the stream should be conducted prior to full-scale operation to confirm chemical dosages and prevent any problems during full-scale operation.

- Until the level of AFFF in the stream is determined, caution should be taken to avoid foaming. Airflow rates should be reduced to 5 scfm, ASH pedestals should be adjusted to minimize overflow, and the clarifier level should be lowered such that skimmer blades are just above water surface. Upon completion of system-fill in the feed mode, a visual evaluation of foaming characteristics of the stream will allow the operator to assess whether or not recirculation of the batch is required to further reduce AFFF levels. If it is not, airflow rates and pedestal position may be adjusted to optimize contaminant removal to the sludge chamber while minimizing the liquid carry over. In the event that recirculation is required, airflow rates and pedestal position may be altered as the foaming is visually seen to diminish.

- Care should be taken to check for possible cross connections between source and discharge locations when treating a stream to avoid the introduction of cleaned water back into the source water. This would have the effect of diluting the influent stream, and cause overdosing of the chemicals, which could be detrimental to the effluent.

- During operation of the system in a feed mode, it is possible to use the sludge pump to recirculate some of the water contained in the sludge chamber back to the first mix chamber for additional processing through the system. This should be done carefully. The waters contained in the sludge chambers are much higher in contaminant concentration than the influent water. The volume of sludge water in the mix chamber should be less than 10% of the influent flow rate coming into that same chamber. However, if defoamer has been used in the sludge chamber, this water should not be reintroduced to the process. This could cause contamination of the effluent with defoamer, which could be undesirable for downstream treatment facilities. Or if the effluent is to be reused for fire-fighting training, the defoamer could have a detrimental affect on the foaming characteristics of the AFFF used in these exercises. If foaming in the sludge compartment persists, the sludge water can be pushed through a hose and sprayed back into the sludge compartment. The spray action of the water will collapse foam collected in the sludge chamber without the need to add additional water volume via the defoaming system.

- One equipment improvement which should be incorporated into future systems is to replace the large compressor (20 hp), currently used to supply air to the ASH modules, sludge pump and level control system, with a small regenerative blower (~3.5 hp) to supply low pressure air to the ASH modules, and a much smaller air compressor (~5 hp) to supply high pressure air to the sludge pump and level controls. This allows for a significant reduction in noise from the system, reduces total amperage drawn by approximately half and reduces energy consumption during operation.

- During the evaluation of AFFF concentration using the foam height measurement technique, care must be taken to provide sufficient filtration for samples prior to evaluation. Filtering of samples should remove all residual fuels, oils and greases in the stream. The inclusion of these materials in a sample during testing will suppress foaming and give a false low reading of AFFF concentration. Suggested filtering is 4 passes through 11-micron filter paper followed by filtering through a 0.45 micron Syrfil device.

- When changing system chemicals, care must be taken to ensure proper flushing of pumps and lines. In cases where the chemical being processed through a pump or line is being changed, the line should be blown out (use air not water to avoid polymers causing thickening problems), and pumps should be disassembled and flushed using air and dry rags. In addition, when switching to a dual polymer system, the anionic polymer should be pumped from chemical pump #2 and the effluent line from this pump moved to discharge to mix chamber #2. The cationic polymer should be pumped through chemical pump #1 and its effluent line moved to discharge into mix chamber #3. Do not switch between anionic and cationic polymers in a single pump; even with copious flushing, the pump and lines tend to clog from the interaction of the two oppositely charged substances.

- In cases where chemicals are changed for a pump, the pump should be calibrated for use with the specific chemical being pumped. This will insure accurate dosing into the system.

- During the initial recirculation of a batch of wastewater, any chemicals being dosed into mix chamber #2 or #3 should be manually initiated to allow the volume of water contained in the mix chambers prior to the chemical discharge point to receive full chemical treatment. For example, upon initiation of recirculation, the polymer being discharged into mix chamber #2 should be run for 2 minutes to allow the 100 gallons contained in mix chamber #1 to receive the second chemical.

- Experience with waste streams containing high VOC and semi-volatiles concentration, especially those associated with industrial solvents, showed they can severely interfere with removal of emulsified oils and greases from the stream by chemical means. The industrial solvents created emulsions with the O&G contaminants that could not be broken without first ridding the stream of the VOC contaminants. This type of stream would require VOC stripping prior to ASH treatment.

- Careful attention should be paid to the source of the wastewater to ensure that the stream is not primarily sludge or free product. The system is designed to separate contaminant from a stream that is primarily water. The introduction of a waste stream with extremely high concentrations of sludge or free product would severely foul the system components.

- Finally, in cases where the waste stream contains AFFF and absolutely no O&G contamination or the O&G concentration is extremely low (<25 ppm) and there is no concern for the removal of the O&G, the stream may be processed without coagulating chemical treatment. This method proved to be as effective at AFFF removal as the alternative dual polymer treatment in these types of streams. Note that if O&G removal is required or if concentration is > 25 ppm, chemical treatment must be used for treatment. Failure to chemically remove the O&G contaminants from the stream may cause fouling of equipment.

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APPENDIX A

POINTS OF CONTACT

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